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## CRITICAL SITUATIONS AND THE FLIGHT SAFETY SYSTEM

### ABSTRACT

By analyzing and defining events, and then sorting them out into two distinct groups, this paper will highlight the similarity and frequency of safety factors in a given time frame. The aim is to comprehend the current level of flight safety and compare it to the situation of some fifteen years ago, regardless of technological improvements. This paper shows critical situations as starting events with possible preventive actions with the aim of preventing the development of events with consequences.

### KEY WORDS

flight safety, aircraft, critical situations, incidents, accidents, filing and comparing

### 1. INTRODUCTION

Given the fact that the aircraft accidents do not happen without a reason [5], and considering the fact that 80-90% of accidents are caused by human error, there are several key points that can be made:

- flying is a high-risk activity in which nothing can be left to chance,
- flight safety depends mainly on prevention of unwanted, unpredictable and uncontrollable situations,
- aircraft accidents are statistically relatively rare occurrences,
- aircraft accidents are events which cannot always be avoided – only their consequences can be minimized,
- certain situations exist that are not regular but rather emergency ones, and they are manifested as emergency situations and accidents which can be influenced,
- research aimed at defining “incidental pilot” profiles is still fairly insufficient,
- the main risk factors in flying activities are: person, aircraft, environment, and mission.

There are several complex elements in the present aircraft accident prevention system, the most important being tracking, filing, and researching of situa-

tions and events that result in irrelevant or no consequences at all, but which are not necessarily reported. We can learn about the “accident mechanism” from the plethora of such situations in which the main culprit is the human factor, and in doing so, improve flight safety. Accident terminology is a particular burden; therefore, for the purpose of this comparative research, names and meanings have been defined for such situations.

Flight safety comparative research has been conducted to determine the level of flight safety today, compared to the situation fifteen years ago. The research included the analysis of flight safety situations that happened at the flight training centre that conducted, and is still conducting, flight training with students and pilots throughout the entire calendar year and across the geographical boundaries of the Republic of Croatia.

### 2. FLIGHT SAFETY AND EVENTS WHICH THREATEN IT

*Flight safety* is a collection of procedures, regulations and laws, which define the movement of aircraft on the ground (water) and in the air, enable and protect human integrity and aircraft resources, prevent unexpected and unwanted situations in the flying activities, and decrease their consequences [7,11].

It is an integral part of flying-related activities focused on eliminating subjective and objective factors that influence the formation of conditions that ultimately result in situations which can threaten human integrity in the form of injuries of different levels, or the integrity of material resources in the form of damage or destruction.

*Flight safety relies* upon prevention of aircraft accidents (unwanted, unexpected, and uncontrolled events), whose foundation is clearly defined by a series of risk factors known as “4M” (Man, Machine, Medium, Mission). The main idea of this system is: *leave nothing to chance...* [8] and one thing is certain: continuous advances in the field of flight safety through preventive action on risk factors and analysis of events

that decrease or threaten flight safety is more than worth the price, because the result is less damage or destruction of aircraft, protection of human life, and saving of resources. From the direct risk factors several others are derived, including the pilot, aircraft commander, crew, which is the last line of defence in the chain of events leading to the development of undesirable situations. It is the crew that directly influences the safety of each flight with its knowledge, skill, discipline, and moral values. The lack of knowledge, poor discipline, presence of vice, and twisted moral values of the pilot often result in too high a price to pay.

The object of research in the flight safety system are causes of events in the aviation activities that require serious preventive action with the aim of preventing the development, but also of decreasing the consequences both for people and material resources.

However, by accepting all of the recommendations stated by the ICAO (International Civil Aviation Organization) – Annex 13, and in particular the Directive 2003/42/EZ of the European Parliament and Board dated 13 June 2003 on civil aviation emergency situations reporting procedures, and the Directive 94/56/EZ as well as other documents, the following can be observed:

- Terms: concepts – phrases that can be found in ICAO and JAR (Joint Aviation Regulations) documents, as well as other specialized literature, need to be defined and their degree established by all of the associations dealing with flight safety. Finally, the term “emergency situation” should be eliminated since it represents all of the events that are not regular, and is contained in other terms such as: *incident, accident, fatal accident, fatal injury, air-*

*plane crash, minor accident, takeoff accident, flying accident, landing accident, forced landing, crash, crash landing.* All these are differently translated in Croatian and it is therefore imperative to make a decent classification and description.

- Statements such as: “the experience has shown that risk factors exist expressed through events that threaten flight safety”, give a hint that no established scientific research system exists.
- The pure stating and listing of events in the aviation activities without an established methodological gradation, rank ordering, classification, and description of events that hint at the risk level in the flying activities, without clear classification criteria, indicate an inappropriate and non-scientific approach in the research of such events (found in the Directive 2003/42/EZ)
- Incompatibility of the current national language standard, in terms of inadequate translation added to the unorganized terminology in the English language make the problem even more complicated.
- The pure stating and listing of events in the Directive (2003/42/EZ) which are intended to be reported on and collected in a unique data base at the European level, demands establishment of classification criteria (not only counting) because the events with consequences and those without cannot and may not be put together.
- The events laid out in the Directive (2003/42/EZ) do exist and offer the possibility of preventive action, because of the number and frequency of events, but require clear classification criteria as follows:
  - based on the place of events: aviation events on the ground or airborne,

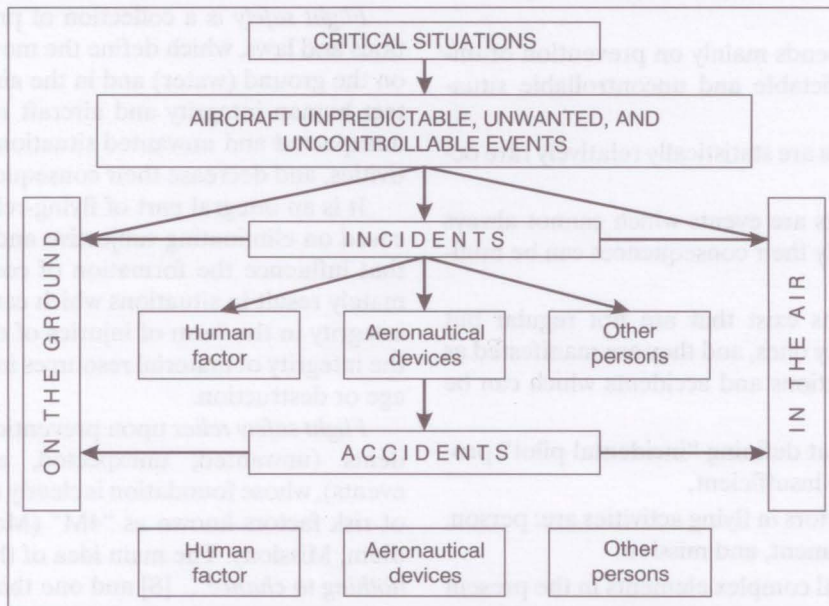


Figure 1 - Correlation between critical situations, incidents and accidents

- based on the consequences for the crew and the aircraft,
- based on the causes of risk factors.
- Therefore, our reasoning goes in the direction of classifying unwanted and hard-to-expect situations that threaten flight safety in the following way.
- The offered classification includes events that can be acted on preventively – critical situations [9,10], incidents [7,11] and accidents [7,11] whose possible acceptance requires research procedure of classification and description with the goal of being specific in considering the risk events occurrence. This kind of risk event defining enables the comparison of the risk levels, offers standardization in understanding of the events themselves, does not put any event in front of the other as in case of “aircraft close encounter” and enables comparison of safety with other types of traffic.

### 2.1 Critical situation – event without consequences

Critical situation is an unexpected, unpredictable, undesirable and uncontrollable event in flying activities which could have had consequences in the form of endangering the human factor through injuries of different intensity or damage of different degree on material goods. Mostly passes without visible consequences and rare material evidence by registration of responsible or endangered persons (crew, flight controllers, other persons, radar records, etc.). Critical situations show that incident could have happened had further development of events not been intentionally or unintentionally prevented.

### 2.2 Incident – event with visible lighter consequences

Air incident is an event in which flight safety has been threatened with visible consequences expressed in material damage of devices, assemblies, equipment, fuselage or engine with damages and lighter injuries of crew or passengers, which hinders safe flight continuation. These damages do not cause the destruction of vital aircraft systems such as: propeller, engine, wings, tail, landing gear and they are repairable at the airport level including also minor damages of other civil or legal persons. If any part or system which is not vital has been destroyed, we talk about serious incident.

Incidents as the events which threaten or disturb flight safety show that accident could have happened had further development of events not been intentionally or unintentionally prevented:

- 2.2.1 *for people*: light injuries of crew, passengers or other persons caused by flying activities in the events on the ground or in the air.

- 2.2.2 *for aircraft or other material devices*: failure, damage or destruction of parts of aircraft systems whose failure, damage or destruction causes flight interruption or the flight becomes unsafe (propeller blade, fractures in engine, damages of flight commands, wings, parts of landing gear, tail, electrical failures or pitot-static installation failures, navigation equipment failures etc.)

### 2.3 Accident – event with visible consequences

An air accident [6,11] is considered an unexpected, unpredictable, undesirable and uncontrollable event in flying activities which threatens flight safety with visible consequences:

- which starts from the moment the crew and passengers have entered the aircraft, till they leave the aircraft,
- where heavier damages of vital aircraft systems or their destruction have occurred,
- which includes heavier wounding, permanent invalidity or death of the crew, including passengers or other persons.

- 2.3.1 *for people*: serious – heavier and heavy injuries of crew, passengers or other persons caused by flying activities and events on the ground, in the air or during the aircraft crash, including permanent invalidity or fatal injury.

- 2.3.2 *for aircraft and other material devices*: heavy damages or destruction of vital aircraft systems (engine, landing gear, wings, tail, fuselage, propeller or rotor system) or entire aircraft, caused by event on the ground, in the air or during the aircraft crash, including damages and destruction on aeronautical devices owned by other legal persons.

## 3. PAST RESEARCH

Research carried out on events that threaten flight safety during the period from 1980-1990 (B. Reljan, Z. Vrsalović, V. Šumanovac, A. Ključanin) in FTO1 (*Flight training organization*), especially in 1989 (see research V. Šumanovac, A. Ključanin: “Correlation between critical situations and other elements of flight safety”) have been used as the base for this research. The definition of critical situation, its classification and description was taken from this research and the given results were used as the base for longitudinal research and comparison of flight safety elements.

#### 4. RESEARCH GOALS

The research goal is, by using the longitudinal and comparative research, to find out the flight safety level during the period from 1997-2005 in FTO2 of events which threatened the flight safety with no evident consequences and allow preventive action. The aim is to find out statistically relevant indicators of numerical values and based on them to try and find out whether it was safer to fly then or today. The 15-year distance between two researches goes in favour of later research because of the development level and the reliability of aviation technology. Having in mind that the level of pilot's knowledge is higher today than 15 years ago, we have still compared the interesting events because a human is always its participant or cause and his safety is an object of our research.

#### 5. RESEARCH METHODS

The data was collected and classified based on the valid flight documentation, reports about critical situations, incidents and accidents, by documentation and statistical method of counting procedure. Data processing was done by combination of different procedures of statistical methods (analysis, table representation, numerical representation with percents of obtained data) analysis and synthesis, deduction and induction research approach by confirmation or rejection.

Based on all the above mentioned, we came to the conclusion about the frequency of events which threaten flight safety and what the system of prevention has to be directed to. Research has also brought out the need to systematically research the causes of aircraft accidents for a longer period within the geographical boundaries of the Republic of Croatia by

systematic factor analysis method of aircraft accident causes (maybe even incidents if it is possible to collect enough data) for which this research could be used as a starting point.

#### 6. HYPOTHESIS

"Flight safety remains at the same level regardless of the research periods". Accepting or rejecting the hypothesis, by comparing the events from the period between 1980-1988 with events from the period between 1997-2005, on the same kind of flying activities in FTO.

#### 7. RESEARCH RESULTS

With research carried out in 2005/2006 in FTO2 we found out that the realised flight time for period from 1997-2005 was 259,507 flights, 519,014 take-offs and landings and 65,016 flying hours. Registered operational data found in the research process of threatening flight safety events in FTO2 during that period were: 192 critical situations, 56 extraordinary events and 7 accidents which made us to transfer 20 extraordinary events in critical situations and 36 events with registered damage, as a consequence, into accidents. Small number of events which had influence on flight safety called out suspicion because of previous researches, so we started to research flight documentation and obtained the following data: 3032 critical situations (192 registered + 2840 unregistered), 36 incidents and 7 accidents with 5 damaged and 2 destroyed aircraft.

In this research we have been using registered statements of pilots about critical situations which happened to them through public and anonymous reports. In anonymous reports we did not get the ex-

**Table 1 - Correlation between safety elements in FTO 1 and 2**

| Safety Elements                | FTO - 1 ( 1980-1988) |                             |                                |                         | FTO - 2 (1997 - 2005) |                          |                                |                        |
|--------------------------------|----------------------|-----------------------------|--------------------------------|-------------------------|-----------------------|--------------------------|--------------------------------|------------------------|
|                                | Number of events     | Event per number of flights | Event per number of operations | Events per flight hours | Number of events      | Event per flight numbers | Event per number of operations | Event per flight hours |
| Critical situation             | 5 012                | 63                          | 124                            | 22                      | 3 032                 | 86                       | 172                            | 21                     |
| Incident                       | 62                   | 5164                        | 10 328                         | 1 794                   | 36                    | 7 209                    | 14 418                         | 1 806                  |
| Accident: heavy damage         | 14                   | 22 870                      | 44 876                         | 7 946                   | 5                     | 51 901                   | 103 802                        | 13 003                 |
| Accident: destroyed aircraft   | 4                    | 80 044                      | 160 088                        | 27 811                  | 2                     | 129 753                  | 259 506                        | 32 508                 |
| Accident: crew death           | 1                    | 320 176                     | 640 352                        | 111 244                 | 0                     | 259 507                  | 519 014                        | 65 016                 |
| Accident: Other person's death | 0                    | 320 176                     | 640 352                        | 111 244                 | 1                     | 259 507                  | 519 014                        | 65 016                 |

Table 2 - Causes of critical situations

| Cause of critical situations            | Number of critical situations |                    | Frequency %        |                    |
|---|-------------------------------|--------------------|--------------------|--------------------|
|   | FTO-1<br>1980-1988            | FTO-2<br>1997-2005 | FTO-1<br>1980-1988 | FTO-2<br>1997-2005 |
| 1. Human factor                         |                               |                    |                    |                    |
| – pilots                                | 3390                          | 1801               | 67.63              | 59.27              |
| – aviation-technical service            | 454                           | 287                | 9.06               | 9.51               |
| – flight controllers, meteorologists    | 340                           | 258                | 6.78               | 8.53               |
| All                                     | 4184                          | 2346               | 83.48              | 77.31              |
| 2. Aviation-technical factor – aircraft | 676                           | 441                | 13.48              | 14.59              |
| 3. Other causes                         | 152                           | 245                | 3.03               | 8.10               |
| Total                                   | 5012                          | 3032               | 100                | 100                |

pected increase in the number of critical situations because the same ones were already registered in official documentation.

The structure of the analyzed 3086 elements which have threatened the flight safety in FTO2, shown in Table 1 through relation between flights, operations and flying hours, shows the following: critical situation comes once in 86 flights, or once in 21 flying hours, and accident comes in every 7209 flights or 1806 flying hours. The structure of 5093 analysed elements which threatened the flight safety in FTO1 directly or indirectly, with or without consequences, on the same sample and with the time distance is shown in the same table as a starting point of quality analysis.

Mean values in this case show that a critical situation comes once in 63 flights, or 22 flying hours and per every 5164 flights or 1794 flying hours there is one accident.

Table 1 shows that during the research period in FTO2 per every 21 flight hours comes one hazardous situation which has the possibility of threatening human factor integrity, most often the pilot, in other words, danger from damaging the aircraft, but those events, by chance or skill of human factor, ended there, they were stopped in progress. For FTO1 critical situation comes per every 22 flying hours which is 4.45% better result than in FTO2 and could not be defined as higher or smaller flight safety considering critical situations only.

Table 2 shows that there has been a substantial decrease in human factors share in causing critical situations at the significance level greater than 6% which was contributed by extreme reduction of pilot's participation of 8%. Although, other human factors enlarged their share, overall there has been a decrease in the number of undesirable events which stayed at the level of critical situation. Consequently, it can be claimed that preventive actions need to be directed to other participants in critical situations and proceed with acting on pilots because aberrance from flight

missions – flight indiscipline is a dominant critical situation with 245 elements and produces 8.1% of all critical situations, and they are caused by pilots which can be corrected by standard or educational methods.

The important thing is that only 20% of flight indiscipline is officially reported which is a considering fact, and the rest is given unofficially or by chance so the acting on those causes is limited.

Important thing to mention is also the great number of stopped flight operations due to poor meteorological conditions or poor judgement, meteorological, i.e. the conditions were not adequate, but the flight operations had started anyway. It leads to conclusion that the communication with the meteorological office was not adequate or the crew on meteorological flight did not have enough experience and knowledge for that kind of mission.

Among critical situations at takeoff, the most important is a large number of low speed take-offs (almost 30%), and on landing most numerous are situations of the late alignment with the runway and landing on all 3 wheels and high alignment or rough landing with low speed as its result. Aviation-technical factor – aircraft stayed at the same level as a cause of critical situations; in other words, it is equally safe if we consider that between 1980-1988 we were dealing with old technology or equally unsafe between 1997-2005 when we were dealing with new generation aircraft, with 441 critical situations and with a share of 14.59%. Those were mostly preventively stopped flights due to electrical failures, abnormal motor operation or partial and incomplete landing gear retraction.

## 8. CORRELATION AND COMPARISON OF EVENTS THAT THREATEN THE FLIGHT SAFETY

With the development of modern aircraft, the intensity of military flying and civil traffic, complexity of

flight training and flight safety, large increase of participants in flying activities, increases the need for flight safety improvement. Struggle for better flight safety could be seen in the possibility of preventive actions through prediction of the events which could lead to threatening of flight safety, i.e. preventing critical situations. Till now, mainly accidents (of all types), even accidents with fatalities were analyzed, but critical situations were not included in serious researches, nor even recorded. Different interpretations of meaning and contents of critical situations have brought to the fact that the predicting possibilities are reduced to "measures should be undertaken....", but which measures and which events, that was not defined because it was not clear what is and what is not considered a critical situation.

Analyzing official reports, of documentation of the period from the beginning of 1980 to the end of 1988 in FTO1 shows the following relation: critical situations: incidents: accidents with serious consequences and death of crew or other persons was 28:12:1. The identical documentation of FTO2, from the beginning of 1997 to the end of 2005 shows the elements in relation 25:6:1. If we compare these data and the information on the worldwide work accident reports, with the following relation: incidents without consequences : light consequences : heavy consequences, it is 300:29:1, we have two alternative conclusions:

1. flight training and flying is being performed at high level of safety,
2. all critical situations, and other events as well are not recorded precisely.

In research of statistic counting of flight training documents, according to valid classification of events which threatened flight safety, based on critical situations (because events with consequences are hard to hide) a better relation was recorded: critical situations : incidents : accidents is shown as 1002:12:1 in FTO1 and 505:6:1 in FTO2. Almost double the relations between events in FTO1 and FTO2 during different time periods shows us the correlation of those events with the flight hours, where the flight hours in FTO2 were half those in FTO1.

Alternative conclusions given before act in dialectical correlation: safe flight training is performed, but higher number of critical situations is being hidden. For full picture of observing the events and the possibility of preventive acting it is necessary to study the correlations between critical situations – incidents - accidents, to take different actions for preventing events which disturb and threaten the flight safety.

The event progress at the interception line at higher level is the moment which connects critical situations, incidents and accidents. The interruption of event by any special procedure by a person directly or indirectly included in flight operations, disconnects

and determines limits of event for which we can say that they threaten the flight safety.

Unlike aircraft accidents, critical situations are more often present in flying activities but not treated well, mostly uncompleted and usually with wrong purposefulness. Usually, critical situations are only counted in statistical data, without getting into cause-effect connections with the more complex and obvious events which threaten the flight safety.

Frequency and numerousness of critical situations and the fact that the human factor is dominant, can be used in researches of "aircraft accidents mechanism" and based on improvement of the preventive system.

Considering critical situations as events which had they not been stopped in progress could have had consequences such as incident or accident, we tried to find the relation between critical situations and other elements which threaten flight safety.

The real number of critical situations is bigger than researched, much bigger than registered and evidenced in valid documentation, but due to a variety of reasons they stay unrecorded. This leads to wrongful treatment of critical situations which is a large problem if we know that only difference between critical situation and accident are consequences (in critical situations there are no consequences or they are hidden). That fact is unknown to us and thus we are further away from the more efficient prevention system in the flight safety system. The relation between critical situations given from research and other elements which threaten flight safety can be shown as follows:

- 84 critical situations led to 1 incident,
- 606 critical situations led to 1 accident – damaged aircraft,
- 1516 critical situations led to 1 accident – destroyed aircraft,
- 3032 critical situations led to 1 accident – death of a person.

If one can believe the statistical indicators, then every 84<sup>th</sup> critical situation the pilot fails to overcome and it becomes an incident and every 606<sup>th</sup> critical situation becomes an accident – damaged aircraft. In every 1516<sup>th</sup> critical situation develops completely with unpleasant and unpredictable results, accident – destroyed aircraft. On an average, every 3032<sup>nd</sup> event which threatens flight safety system, most often becomes an accident with fatalities as consequence.

If we accept the statistics, as a "correct sum of incorrect data" then we can doubt these indicators as well. We have checked and monitored the presented facts in almost a decade and had many positive results on the plan of prevention. Since aviation is a high risk profession we had to accept the fact that there are events which cannot be prevented for any, at least up to now known reasons.

## 9. CONCLUSION

Based on this research, documents analysis and comparison with the earlier results, the basic conclusions are:

1. Flying activities have plenty of critical situations whose centre is human factor as a participant, cause and, at the same time, a factor which prevents critical situations by his prediction and preventing actions.
2. Analyzing official reports, documentation in FTO1 shows the following relation: critical situations : incidents : accidents with serious consequences and death of crew or other persons is 28:12:1. Research in FTO2 shows the elements in relation 25:6:1. If we compare the data and the information on the worldwide work accident reports, with the following relation: incidents without consequences : light consequences : heavy consequences is 300:29:1 we can claim that:
  - flight training and flying is performed at high level of safety and all critical situations or other events are not precisely recorded.
3. Research shows that every 84<sup>th</sup> critical situation the pilot fails to overcome becomes an incident and every 606<sup>th</sup> critical situation becomes an accident – damaged aircraft. In every 1516<sup>th</sup> critical situation the development is completed and there are unpleasant and unpredictable results, accident – destroyed aircraft. On an average, every 3032<sup>nd</sup> event which threatens the flight safety system most often becomes accident with fatality as a consequence.
4. Carried out research in its comparative version shows that flying activities today are slightly less safe than fifteen years ago, although it does not have statistical importance.
5. The number of critical situations enables, if their monitoring is systematically used, to identify lots of elements which can cause aircraft accidents, i.e. it gives us opportunity to predict and preventively act on undesirable and unpredictable events.
6. The most important role in the occurrence and reduction in the number of critical situations is human factor, whose personal characteristics and professional skills need constant improvement due to flight safety.

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### SAŽETAK

#### KRITIČNE SITUACIJE I SIGURNOST LETENJA

*Analizom kritičnih situacija, nezgoda i nesreća u dvije zrakoplovne organizacijske cjeline, njihovim, brojanjem, evidentiranjem i razvrstavanjem nastoji se ukazati na sličnost i učestalost pojava kroz određeni vremenski period, a sve u svrhu spoznaje razine sigurnosti letenja danas u odnosu na razdoblje prije petnaestak godina, bez obzira na tehnički i tehnološki razvoj. U radu se kritične situacije prikazuju kao početni događaji na koje je moguće preventivno djelovati, u svrhu sprječavanja njihovog daljnjeg razvoja u događaje s posljedicama.*

#### KLJUČNE RIJEČI

*sigurnost letenja, zrakoplov, kritične situacije, nezgode, nesreće, evidentiranje i kompariranje*

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